Quantification of oxidative stress and physiological parameters due to schoolbag carriage in normal, overweight/obese male schoolchildren of West Bengal.

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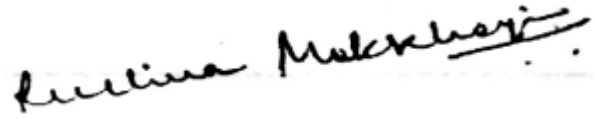

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I. Abstract

Background: The physical activity of heavy schoolbag carriage entails a plethora of physiological responses. During physical activity investigations, both intensity (schoolbag load) and individual characteristics (BMI) are vital as they influence physiological response. Obesity affects millions of Indian children. Existing guidelines disregards BMI. Energy expenditure in obese BMI can induce greater oxidative stress for the same workload compared to normal BMI. Physical activity is also associated with improved cognitive parameters, a crucial aspect of learning. Better cognition associates with improved posture. So, schoolbag carriage must be investigated for different BMI categories encompassing physiological cardio-pulmonary responses, cognition, posture and oxidative stress.

Methodology: Male schoolchildren (10-15 years of age, n=60) were divided into undernutrition/normal and overweight/obese BMI categories having evaluated their anthropometric parameters. They walked with schoolbags weighing 0, 4, 8, 12 and 16% load of bodyweight for 20-minutes. During the walk, cardio-pulmonary response and energy expenditure was assessed by metabolic analyzer COSMED k4b2. Pain, cognition and posture were evaluated via standard methods. Saliva was collected before and after each walk to evaluate the oxidative stress parameters.

Results: All anthropometric parameters were significantly different ($p<0.05$, ANOVA) in the two BMI categories. Heart rate increased linearly till 8% load carriage in normal BMI, but such observation could not be drawn for overweight/obese. Pulmonary parameters- tidal volume, pulmonary ventilation and volume of oxygen consumed were significantly different for various loads of schoolbag and higher in overweight/obese BMI ($p<0.05$, ANOVA). Cognitive parameters improved after walking without schoolbag (0% load) and after walking with 4% load. Similar results were observed for handgrip strength. Pain in shoulder, back increased for 8, 12 and 16% loads with lower pain reports in normal BMI ($p<0.04$, ANOVA). Postural angles worsened for 16% loads in normal BMI and 8% loads in overweight/obese BMI ($p<0.05$, ANOVA). FRAP and TAC showed physiological adaptation for 8% load in normal BMI and for 4% load in overweight/obese BMI. Observations from Griess and Saville assay for nitric oxide and reactive nitrogen species assessment were similar.

Conclusion: Cardio-pulmonary parameters, perceived pain and oxidative stress responses show alterations for normal and overweight/obese BMI. The same workload of schoolbag carriage is more taxing for overweight/obese individuals and puts them more at risk than normal BMI

individuals. Guidelines for schoolbag carriage must be different as per BMI. While schoolbags weighing 8% load of bodyweight is safe for normal BMI, 4% load is deemed to be safe for overweight/obese BMI.

II. Introduction

School going children, irrespective of how sedentary a lifestyle they lead, regularly perform a mandatory physical activity in the form of schoolbag carriage. The textbook-based education system in India, entails a very demanding school curriculum [1]. Exiguous resources like lockers, digital classrooms, laws on school bag load limits elevates the schoolbag load not having negated the necessity of its carriage. This causes physical loading and concomitant derogatory physiological responses such as musculo-skeletal pain [2], lumbar lordosis [3], low back pain [4]. Schoolbag carriage has mostly been investigated in terms of pain manifestation, and scarcely for muscle activity [5], cardio-pulmonary response [6], physical arrangement of body parts or posture [7].

The most recent guidelines on schoolbag carriage in India was introduced by the Ministry of Human Resource Development on 20th November, 2018 [8]. An office circular was introduced which delimited the schoolbag loads to 1.5 kg, 2-3 kg, 4kg, 4.5 kg and 5 kg for classes I-II, III-V, VI-VII, VIII-IX and X respectively, without addressing the vital aspect of a child's bodyweight. Many existing recommendations state the safe limit of schoolbag load to be 10-15% of bodyweight [9,10]. The absolute weight of the schoolbag based on this percentage, differs substantially for a child having high bodyweight compared to a child having lower bodyweight. This might be the reason why subsequent investigations report the 10-15% limit to be physiologically unacceptable [11,12].

Excess bodyweight is mostly measured using BMI (kg/m^2) due to its ease of measurement via height and weight. Furthermore, being inexpensive nature and its applicability to the population at large [13] makes it most popular method of classification. BMI is intricately linked to physical activity. A physical activity is evaluated mainly in terms of cardio-pulmonary response like heart rate, pulmonary ventilation, carbon dioxide expired, oxygen uptake, etc. It has been reported that oxygen uptake varies significantly between individuals belonging to different BMI groups- obese/ non-obese [14]. Thus, the response to physical activity is different in obese and non-obese groups. Being a physical activity, schoolbag carriage may also affect obese and non-obese groups differentially. This is an area incorporating a research lacuna that has been scarcely delved into. A

recent study reports India to have more than 14.4 million obese children [15]- a very considerable proportion of the population. In this scenario, it is of vital importance to evaluate schoolbag carriage in terms of BMI and design safe load limits with the goal to safeguard the emergent population. Apart from BMI few other anthropometric tools also provide information about the nutritional status of an individual, like, waist to hip circumference, waist to height ratio, etc.

The physiological response to a physical activity embodies two of its critical aspects- the intensity of physical activity [16] and physical characteristics of the individual performing it [17]. Pertaining to schoolbag carriage, these aspects correspond to variously loaded backpacks, where, carrying higher loads of schoolbag equates to higher intensity physical activity depending on the bodyweight of the child carrying it. Intense physical activity is cataloged to consume more energy and generate oxidative stress in the body [18–20]. Thus, carrying heavy schoolbags may also lead to oxidative stress in the body. Moreover, since non-obese and obese individuals respond differently to physical activity, it also reasonable to hypothesize that schoolbag carriage will generate varying levels of hypoxic conditions leading to oxidative stress in the body.

Oxidative stress generates, reactive oxygen species (ROS) in the body which cause potential harm to lipids, proteins and DNA [21]. A common example is ROS-mediated lipid peroxidation forming malondialdehyde (MDA) as a by-product [22]. MDA measurement can provide information about the oxidative stress status in the body. Protection against oxidative stress is provided by antioxidants naturally present in the body [23] as well as supplementation by dietary antioxidants [24]. So, measurement of dietary antioxidants intake is crucial during evaluation of antioxidant status. Antioxidants target nitric oxide signaling [24], which causes vasodilation and help in regulating the microcirculation. However, NO may react with high quantities of ROS forming Reactive Nitrogen Species (RNS). So, it's advisable to measure the NO and RNS along with ROS from bio-fluids.

The most commonly used diagnostic bio-fluid is blood which invasively obtained via a syringe. This is not exempt from the concomitant disadvantages of any invasive procedure such as infections, pain and the need for expert personnel. This compels exploration of non-invasive diagnostic tools, especially for children. One such bio-fluid obtained non-invasively is saliva. Blood contents are justly reflected in saliva and its multiple biomarkers make it useful for multiplexed assays [25]. Salivary measurement of oxidative stress and antioxidant status is widely accepted [26].

Following oxidative stress, the increased oxidative stress index and compounds derived from reactive oxygen metabolites serve to be potential fatigue biomarkers [27]. Fatigue is a condition that is often reported in association with carrying heavy schoolbags [28]. Fatigue is the feeling of extreme tiredness characterized by acute inability to perform physically and mentally [29]. While physical activity augments mental fatigue [30], mental fatigue can heighten the perceived exertion thereby limiting physical capabilities [31].

Mental fatigue contributes to cognitive dysfunctions [32]. The American Psychological Association defines cognition as "all forms of knowing and awareness, such as perceiving, conceiving, remembering, reasoning, judging, imagining, and problem solving" [33]. Physical activity and its effect on cognition is well-documented [34]. Evaluating deviations in cognitive ability due to the physical activity of schoolbag carriage is critical given that the entire school curriculum revolves around learning during which cognitive and motor pathways are operational. Cognitive performance is also known to be affected by body postures [35]. Postural assessment during heavy schoolbag carriage indicates increase in trunk flexion [36], head forward lean, shoulder and cervical postures [37]. These changes in posture can affect the cardio-pulmonary functions [38]. Hence, the main aspect of a physical activity, that is, the cardio-pulmonary response, like heart rate, pulmonary ventilation, breathing pattern must be evaluated alongside posture to evaluate the physical activity of schoolbag carriage in a holistic way.

Assessment of cognition, along with the physiological response integrating heart rates, pulmonary response, energy expenditure, oxidative stress and posture due to schoolbag carriage in children belonging to different BMI categories can enable an all-encompassing approximation of the stress generated in the body due to schoolbag carriage.

III. Objectives

Objective 1: Anthropometry and body composition

Objective 2: Assessment of cardio-pulmonary response, perceived and cognitive parameters

Objective 3: Assessment of oxidative stress

IV. Methodology

Study Design:

The work plan for the study has been represented in Figure 1. The study was approved by the Institutional Ethical Committee (Human), Presidency University (PU/IEC(H)/CL/A01/2018). All data collection was performed complying to guidelines of Helsinki Declaration.

Guardians were approached for the study. Participation in the study was contingent upon obtaining signed consent from guardians. On obtaining the signed consent, the participants were enrolled in the study and their anthropometric parameters- height, weight, MUAC (Mid-Upper Arm Circumference), CC (Calf Circumference), WC (Waist Circumference), HC (Hip Circumference), ChC (Chest Circumference) were recorded. Based on the calculated index of BMI the participants were grouped into different BMI categories- undernutrition, normal and overweight/obese categories. During the study, no significant difference was obtained for the studied parameters among under-nutrition and normal BMI category. Therefore, the participants were grouped into 2 categories based on their BMI- normal and overweight/obese.

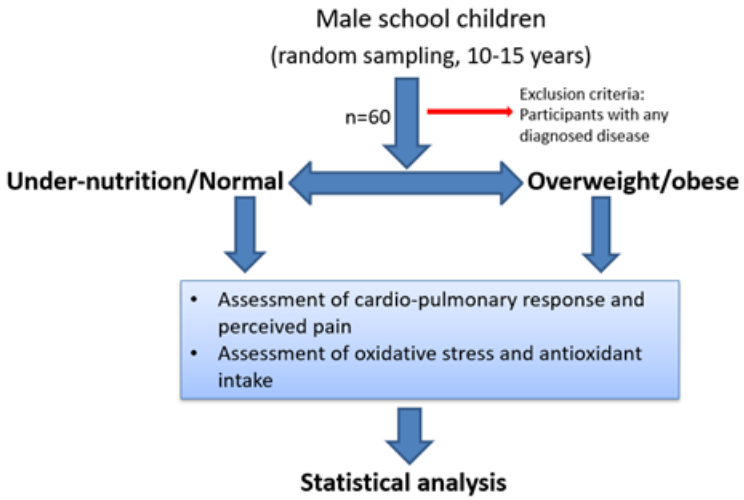

Figure 1: Work plan

a. *Sample size determination*- Sample size for the study was determined by power test (power cut-off 90%, confidence interval=99%) based on a previous study that investigated the change in oxidative status among before and after physical activity exercise [39]. As per the sample size determined, 30 participants in each of the two BMI categories were opted. Calculation-

$$n = \frac{\left(\sigma_1^2 + \sigma_2^2\right)\left(z_{1-\alpha/2} + z_{1-\beta}\right)^2}{\Delta^2} = \text{sample size for each group}$$

where, σ_1 and σ_2 are variances of the two groups,

Δ is the difference between the two means

$Z_{1-\alpha/2}$ is the Z-score for preferred significance level

$Z_{1-\beta}$ is the Z-score for power (0.84 for 80% statistical power is generally used)

b. *Justification of age group*- The age range of 10-15 years is one of expeditious growth not only physically but also mentally [40]. Musculo-skeletal pain in these years, is the prodrome to diseases in adulthood [41].

c. *Subject selection*- Male subjects aged (10-15 years) were included in the study. Since the study design included BMI, targeted sampling was performed to include participants from various BMI categories. Subjects were included from all socio-economic conditions for various BMI categories as such the results were not influenced by their Socio-Economic Status (SES).

d. *Exclusion criteria*- Athletes, children with any congenital or mental disorder, under medication and females were excluded from the study. The age range involved in the study coincides with menarche and the female sex hormones such as estrogen reportedly have antioxidant properties [42] which can interfere with the inferences drawn.

e. *Conditions during the walk*- Each participant had to walk on 5 separate occasions, either with backpacks weighing 4%, 8%, 12%, and 16% load of their body weight or without any backpack (0% load of bodyweight) for 20 minutes (thus, total number of walks evaluated for 60 participants, n=300). The loads were applied in random order to prevent the effect of graded load. The walks were conducted on a flat surface, using an ergonomically designed backpack placed at the mid-back region, carried on both shoulders. The backpacks were packed taking care of equal distribution of load throughout. Participants adopted a pace preferred by them to mimic the real-life conditions. The environmental temperature during walks did not exceed 28°C and 50% relative humidity. The walks were terminated before 20 minutes if the participant reported fatigue and/or pain expressing the wish to stop.

The entire work flow has been represented in Figure 2.

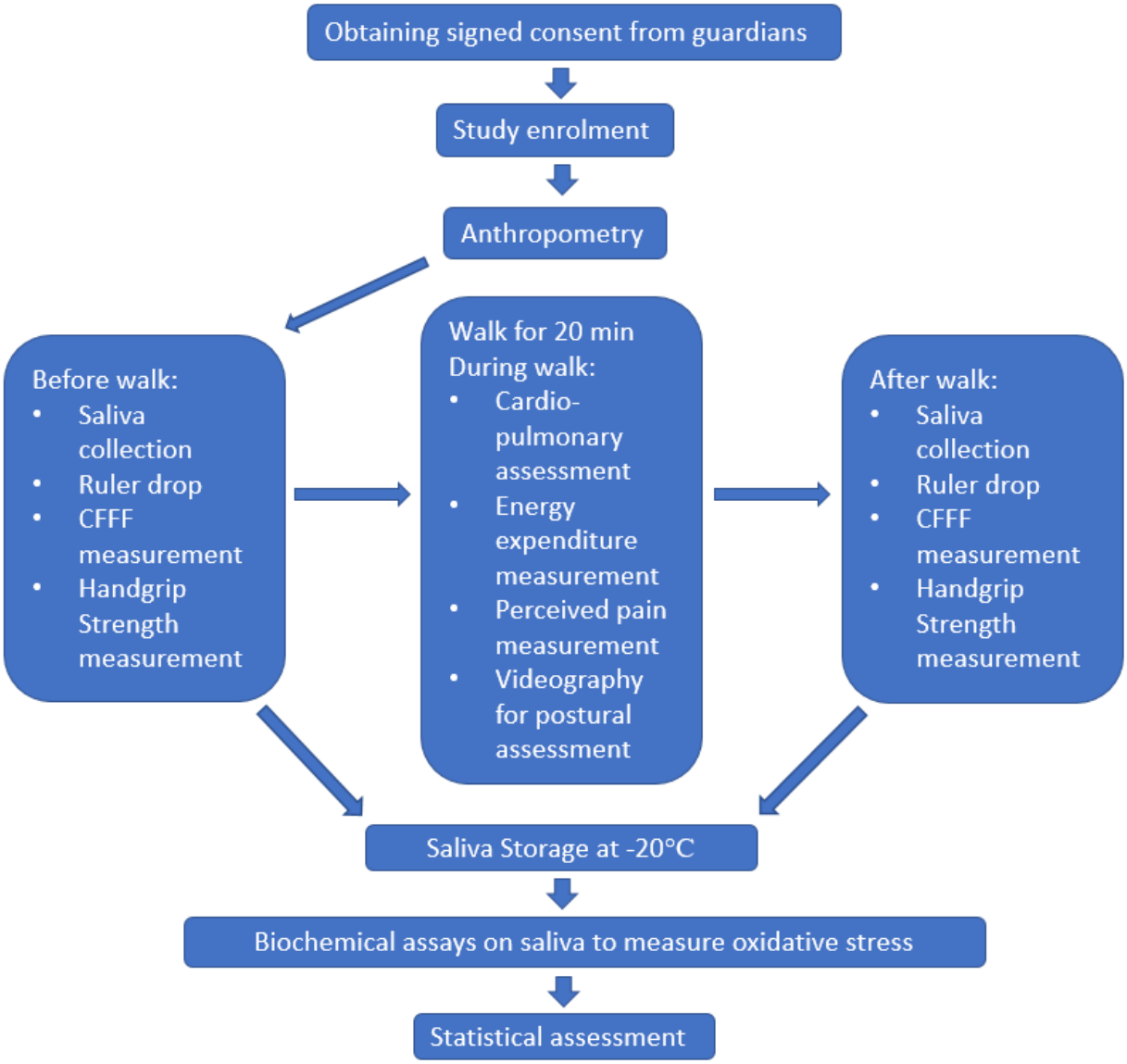

Figure 2: Work flow

f. *Saliva collection*- Unstimulated saliva was collected by passive drooling [43].

g. *Methodology for Objective 1- Anthropometry and body composition*

Anthropometry: Height, weight, mid-upper arm circumference (MUAC), calf circumference (CC), waist circumference (WC), hip circumference (HC) and chest circumference (ChC) were assessed for all the participants. Indices calculated were body mass index (BMI) [44] and waist-height ratio (WHtR) [45].

Body composition analysis: Bioelectrical impedance method (BodyStat 1500MDD) [46] was employed for measurement of body fat percentage. A weak electric current pass through the body

and the resistance or impedance to the flow of current is measured to estimate lean (muscle) mass and fat percentage in the body.

h. *Methodology for Objective 2- Assessment of cardio-pulmonary response, perceived and cognitive parameters*

The following variables were measured during each walk:

Heart rate: It was measured using the heart rate monitor (POLAR) [47]. The polar belt was worn around the chest with the sensor placed above the heart and information transmitted to a wristwatch.

Pulmonary parameters (like pulmonary ventilation, volumes of oxygen and carbon dioxide expired, oxygen consumption, breath counts, inspiratory and expiratory times) and energy expenditure: They were measured using a metabolic analyzer K4b2 (COSMED) [48]. It recorded information for each breath.

Perceived pain: pain is a subjective parameter, whose perception differs among individuals. The subjective pain was mapped during the entire walk session for the whole-body using questionnaire method [49] standardized in Indian children.

Posture analysis: The walks were video graphed using Nikon D3500 camera kept at 2 meters from the walking platform. Still shots were taken from each video (total n= 1606) and different postural angles (cranio-vertebral angle (CVA), cranio-rotation angle (CRA), neck flexion (NF), head flexion (HF), trunk flexion (TF), shoulder angles (SA)) were measured using Kinovea software (V 0.9.5) [50].

Cognitive ability: The tests for cognitive ability were measured twice- once before and once after each walk to avail information about change induced by schoolbag carriage. Cognitive ability was measured using the ruler drop method [51]. Lower reaction time indicates better cognition. A graded ruler dropped from the eye level is the visual cue for catching it as soon as possible. The distance at which the ruler is caught is recorded. Since the ruler drops under the influence of gravity, the time taken to react to the visual cue or the reaction time is calculated from the formula:

$$s = ut + \tfrac{1}{2}at^2$$

Where, s = distance on graded ruler where its caught

u = initial velocity of ruler (always nil)

t = reaction time

a = acceleration due to gravity

This was further supplemented by assessment of Critical Flicker Fusion Frequency (CFFF) which not only appraised cognition but also provided information about fatigue in the participant by gauging the change in ocular fatigue [52]. The measurement involves a flickering light, the frequency of the flicker can be controlled by the researcher. At high frequencies, the flicker can't be detected and the light appears to be still. This point serves to be the frequency where the flicker fuses or the CFFF. Higher the fatigue, lower is the CFFF. Handgrip strength was assessed before and after each walk to reiterate fatigue assessment [53]. Higher the fatigue, lower is the grip strength. Grip strength is especially important for schoolchildren since most of the activities in the curriculum like writing, typing, playing musical instruments or games require hand dexterity.

i. *Methodology for Objective 3- Assessment of oxidative stress*

Salivary analysis: Saliva collected before and after each physical activity regime and was immediately stored at 4°C and subsequently stored at -20°C. The 60 participants walked on 5 different occasions thus yielding 10 saliva samples each (total N=600). The samples were assessed for various markers of oxidative stress via the following tests. Ferric reducing antioxidant power (FRAP) assay (n=600) to assess non-enzymatic antioxidant level [54]. Total antioxidant capacity (TAC) (n=600) yields an estimate of enzymatic and non-enzymatic antioxidant levels [55]. Glutathione peroxidase (GPx) enzyme activity was measured biochemically (n=80) [56]. Thiobarbituric acid-reactive substances (TBARS) (n=600) provided an estimate of lipid peroxidation [57]. Griess reaction (n=600) helped to assess NO, while Saville reaction (n=600) assessed Reactive Nitrogen Species (RNS) [58]. Comet assay was done to determine DNA damage due to oxidative stress [59].

D*aily antioxidant intake*: Diet survey was done via 24 hours recall method [60]. The standard contents of antioxidants in each food item was obtained from the National Institute of Nutrition (ICMR) [61].

Statistical analysis: k4b2 metabolic analyzer recorded each breath throughout the duration of physical activity. Cardio-pulmonary parameters and energy expenditure for each breath was tabulated into an Excel sheet. Since the number of breaths taken by individuals differ on different occasions of walk, all data were grouped into 10 second intervals. Thus, after the Excel sheets were processed, each participant had 120 datapoints irrespective of the number of breaths taken. These sheets were further compiled for statistical analysis.

All statistical analysis comparing the 3 groups were performed using SPSS software (V25), R software and MS Excel. The data for all variables included in the study was checked for their

distribution. Upon obtaining normal distribution, the data was further analyzed using mean (±SD), t-test or ANOVA as applicable to test for significant difference.

V. Results

Results for Objective 1:

Anthropometry:

Table 1: Anthropometric parameters of the participants

BMI Category		Age (Years)	Height (cm)	Weight (kg)	WC (cm)	HC (cm)	MUAC (cm)	CC (cm)	ChC (cm)	BMI (kg/m^2)	WHtR
Normal (n=30)	Mean	12.1	144.9	34.9	63.9	74.4	20.4	27.4	68.9	16.4	0.4
	(±SD)	1.25	11.84	8.07	6.89	7.78	2.34	3.12	7.39	1.97	0.04
Overweight/ obese (n=30)	Mean	11.9	154.2	55.9	82.8	88.1	26.6	33.9	86.2	23.3	0.5
	(±SD)	1.47	10.86	12.74	12.16	16.41	4.53	5.99	13.41	3.35	0.07

Age was not significantly different in the two BMI categories ($p>0.05$) but all other anthropometric parameters were significantly higher in overweight/obese group compared to the normal group as per ANOVA ($p<0.05$).

Bio-Electrical Impedance for Body Composition analysis: The body fat percentage correlated positively and strongly with BMI of the participants (Spearman $r=0.8$, $p<0.05$, $n=10$). These results all conformed with published literature that classify normal and overweight/ obese children as per anthropometric parameters.

Results for Objective 2:

Cardiopulmonary parameters were measured as detailed in the methods section. Each parameter is represented for normal (N) and overweight/obese (O) categories for walks with 0, 4, 8, 12 and 16% of bodyweight.

Cardio-pulmonary parameters:

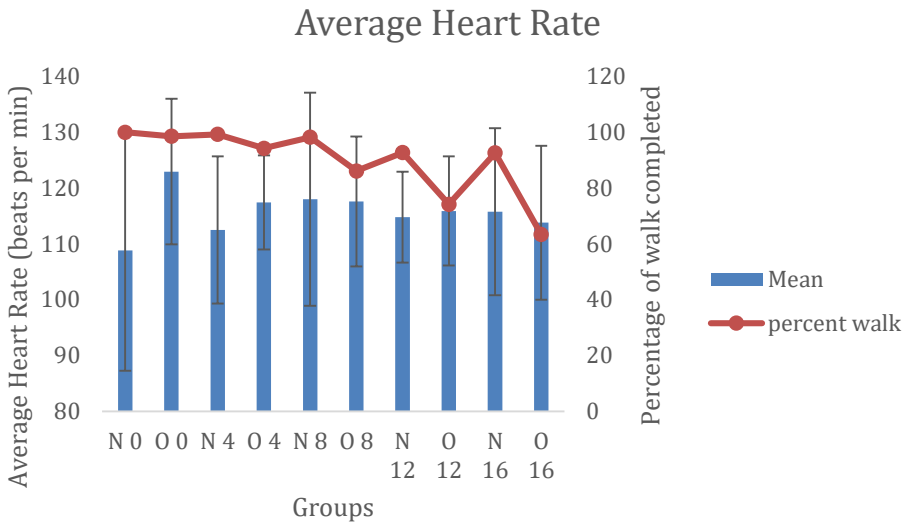

Figure 3: Average heart rates during different walks for different BMI (n=60). *N0-Normal BMI participants for 0% load carriage, O0-Overweight/obese BMI participants for 0% load carriage, N4-Normal BMI participants for 4% load carriage, O4-Overweight/obese BMI participants for 4% load carriage, N8-Normal BMI participants for 8% load carriage, O8-Overweight/obese BMI participants for 8% load carriage, N12-Normal BMI participants for 12% load carriage, O12-Overweight/obese BMI participants for 12% load carriage, N16-Normal BMI participants for 16% load carriage, O16-Overweight/obese BMI participants for 16% load carriage.*

While the lowest average heart rate was found in normal category participants when not carrying any load, the highest average heart rate was found in overweight/obese category individuals when carrying no load (Fig 3). Furthermore, the normal weighted children exhibited a steady increase in heart rate till 8% of body weight load carriage after which no further increase was observed. This indicated that for normal category participants, a schoolbag weight till 8% can increase the heart rate as is the normal physiological response to increasing workload [62]. Carrying 12 and 16% loads does not regulate the heart rate correspondingly, and can cause adverse consequences. On the contrary, no such pattern was observed amongst the obese category participants. This indicates that heart rate regulation of load carriage is better in normal BMI children till 8% load but fails in overweight/ obese BMI children with respect to school bag carriage.

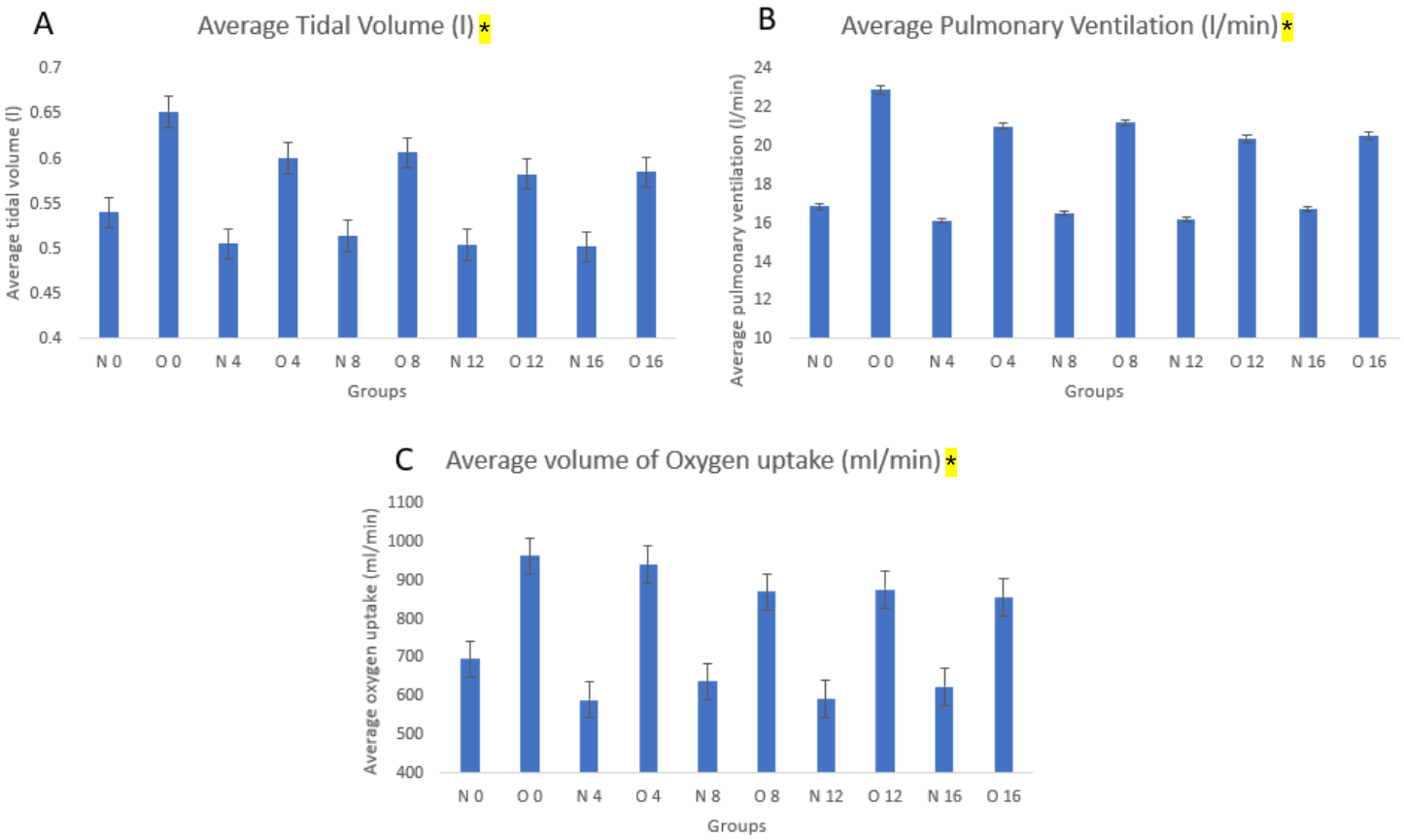

Figure 4: Average pulmonary parameters during different walks for different BMI (n=60). *N0-Normal BMI participants for 0% load carriage, O0-Overweight/obese BMI participants for 0% load carriage, N4-Normal BMI participants for 4% load carriage, O4-Overweight/obese BMI participants for 4% load carriage, N8-Normal BMI participants for 8% load carriage, O8-Overweight/obese BMI participants for 8% load carriage, N12-Normal BMI participants for 12% load carriage, O12-Overweight/obese BMI participants for 12% load carriage, N16-Normal BMI participants for 16% load carriage, O16-Overweight/obese BMI participants for 16% load carriage. (* Significantly different for the 10 groups as per ANOVA, p<0.05)*

Tidal volume (l) (Fig 4A), Pulmonary Ventilation (l/min) (Fig 4B), Volume of Oxygen uptake (ml/min) (Fig 4C) were significantly higher ($p<0.05$, ANOVA) among overweight/obese subjects for different loads carried. Evaluation of pulmonary parameters indicates that normal BMI category participants portray normal pulmonary physiological response at all loads of schoolbag carriage. However, the pulmonary parameters for overweight/obese participants were all higher than that of the normal participants, but decreased gradually with increase in load of schoolbag

carried. This indicates that school bag carriage is more taxing for the obese/ overweight children compared to the normal participants for the same workload as per pulmonary parameters.

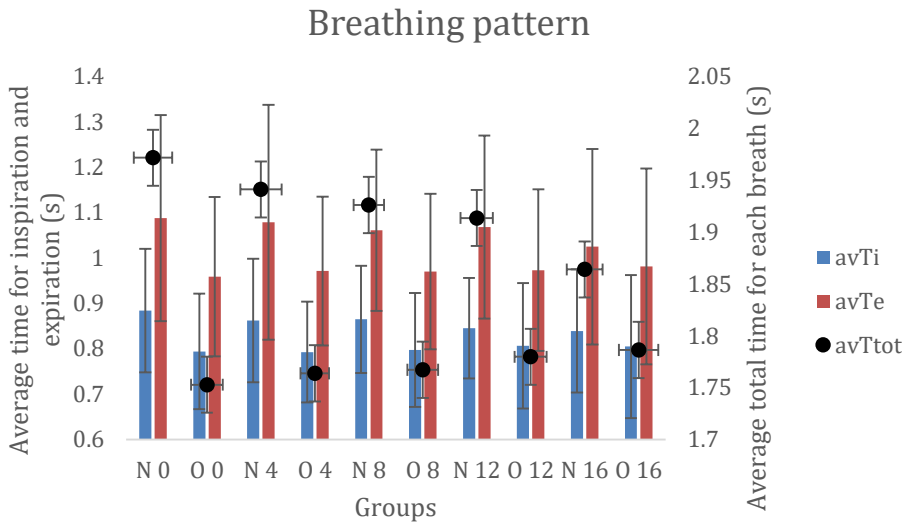

Figure 5: Breathing pattern during different walks for different BMI (n=60). *N0-Normal BMI participants for 0% load carriage, O0-Overweight/obese BMI participants for 0% load carriage, N4-Normal BMI participants for 4% load carriage, O4-Overweight/obese BMI participants for 4% load carriage, N8-Normal BMI participants for 8% load carriage, O8-Overweight/obese BMI participants for 8% load carriage, N12-Normal BMI participants for 12% load carriage, O12-Overweight/obese BMI participants for 12% load carriage, N16-Normal BMI participants for 16% load carriage, O16-Overweight/obese BMI participants for 16% load carriage. Average Time of inspiration (AvTi, seconds), Average time of expiration (AvTe, seconds) and Average total time for each breath (*AvT_{tot}*, seconds).*

Average Time of inspiration (AvTi, seconds), Average time of expiration (AvTe, seconds) and Average total time for each breath (AvT_{tot}, seconds) was significantly different ($p<0.05$, ANOVA) among the two BMI categories for different loads carried (Fig 5). Normally, the time of expiration is twice as long as the time taken for inspiration [63]. The normal ratio of ventilation is therefore 2, if the ratio evaluates to be 1, it is known as equal ratio ventilation and a ratio lower than 1 pertains to inverse ratio ventilation. Though all the ratios from the Fig 5 are closer to equal ratio ventilation, the highest ratio (about 1.26 for normal and 1.23 for obese) was evaluated to be for 4 % load carriage. This indicates that 4% load carriage is a safe load to carry as per breathing times.

Energy Expenditure:

Total Energy Expenditure (Kcal) was significantly different ($p<0.05$, ANOVA) among the two BMI categories for different loads carried (Fig 6).

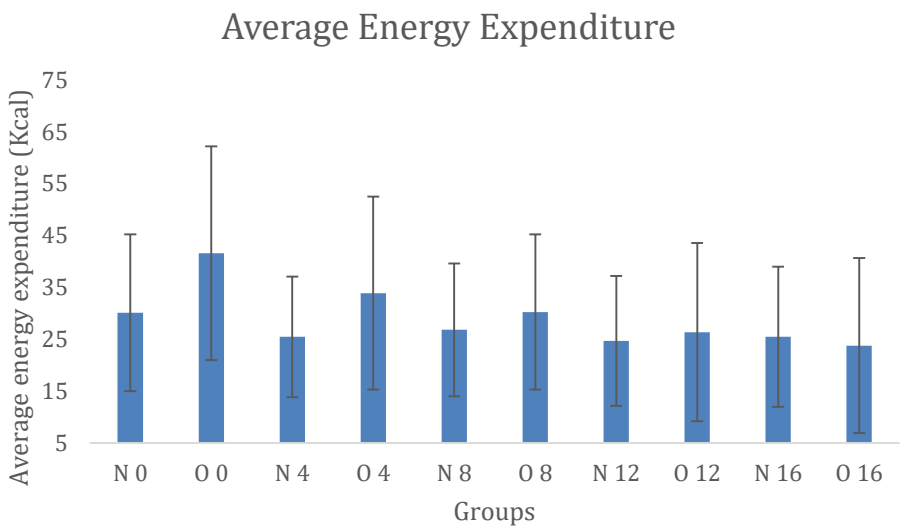

Figure 6: Breathing pattern during different walks for different BMI (n=60). *O0-Overweight/obese BMI participants for 0% load carriage, N4-Normal BMI participants for 4% load carriage, O4-Overweight/obese BMI participants for 4% load carriage, N8-Normal BMI participants for 8% load carriage, O8-Overweight/obese BMI participants for 8% load carriage, N12-Normal BMI participants for 12% load carriage, O12-Overweight/obese BMI participants for 12% load carriage, N16-Normal BMI participants for 16% load carriage, O16-Overweight/obese BMI participants for 16% load carriage.*

Total Energy Expenditure (Kcal) was significantly different ($p<0.05$, ANOVA) among the two BMI categories for different loads carried (Fig 6). Energy expenditure decreased for increasing loads in overweight/obese category. This may be mainly due to decreased pace of walking and inability to walk for 20 complete minutes while carrying schoolbags.

Evaluation of cardio-pulmonary parameters in objective 2 finds that schoolbag weighing 8% of bodyweight is safe for normal BMI category subjects. Given that parameters indicate schoolbag

carriage to be more taxing for overweight/obese participants, schoolbags weighing 4% of bodyweight is safe for them.

Adopted speed:

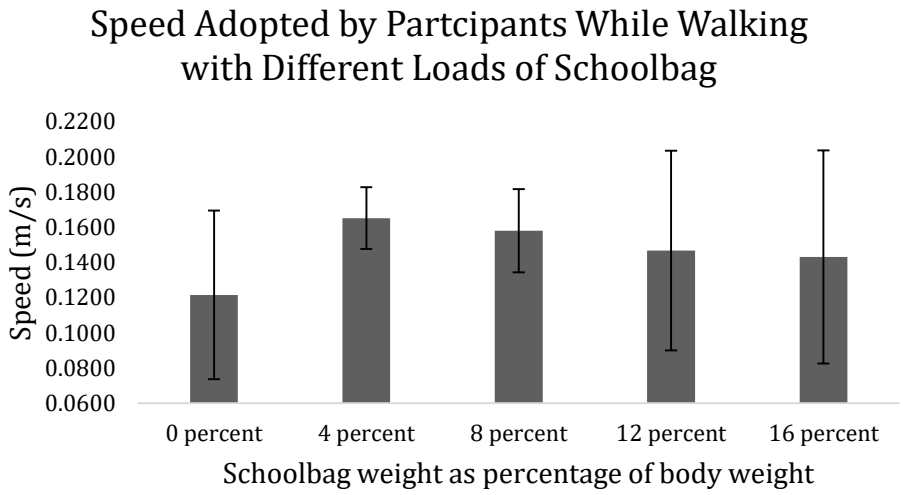

Figure 7: Speed adopted during different schoolbag loads

Increase in schoolbag load corresponded to decrease in preferred speed (Fig 7). Similar observations were made for both BMI categories so the results have been represented without the BMI category divisions.

Cognitive parameters:

As weight carriage affects cognitive parameters, changes in these parameters were assessed as per methods detailed earlier in the method section. Similar observations were made for both BMI categories so the results have been represented without the BMI category divisions for better visual perception.

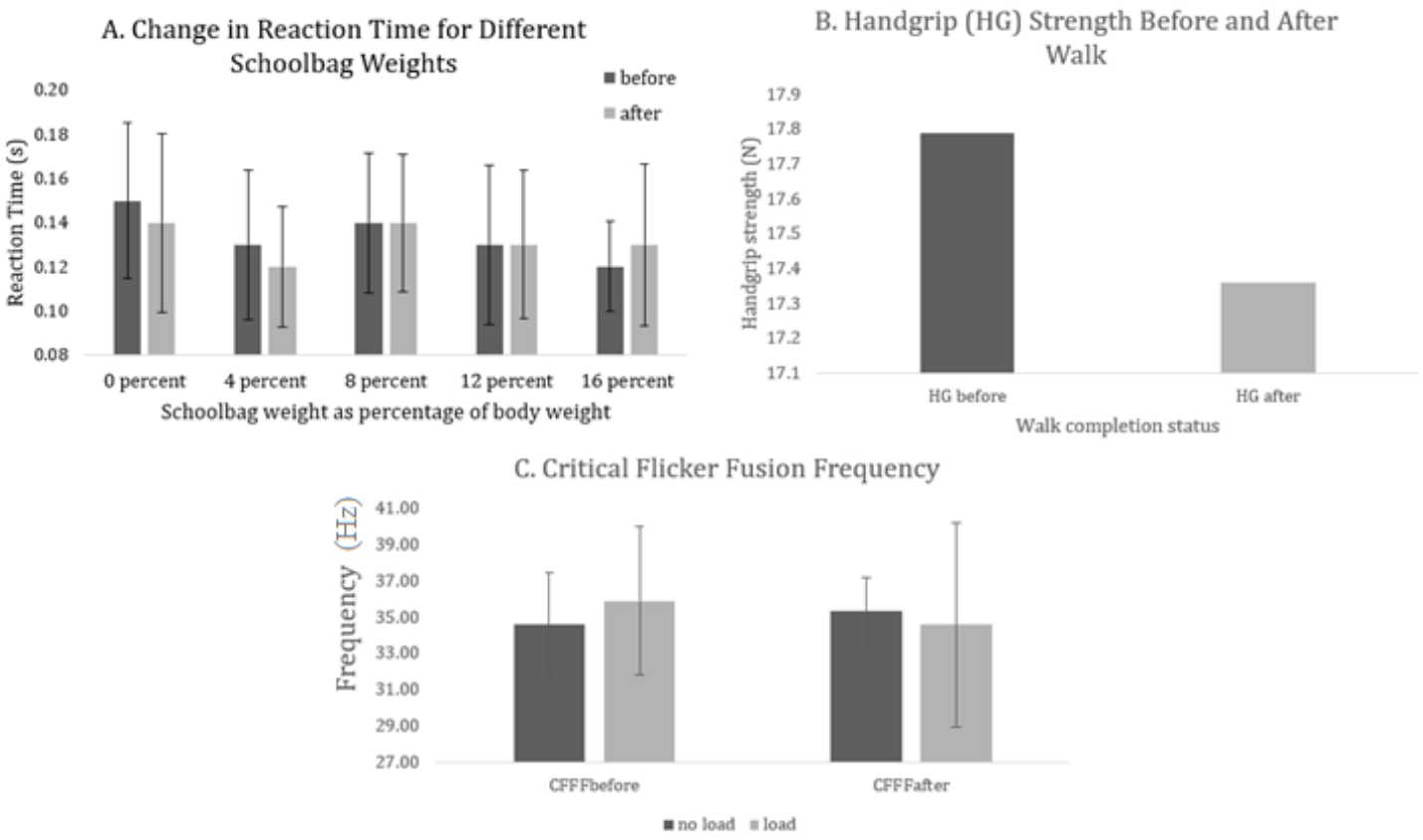

Figure 8: Cognitive parameters for schoolbag carriage. (A) Reaction time, (B) Handgrip strength, (C) Critical Flicker Fusion Frequency.

Reaction time improved after 0 and 4% load carriage while it worsened after 16% load carriage (Fig 8A). Handgrip strength decreased after backpack carriage (Fig 8B). CFFF increased after walking without any load while it decreased after carrying schoolbag (Fig 8C). All these parameters indicated that school bag carriage does induce cognitive changes in children which could imply long term implications in school performance.

Perceived pain (n=80 walks):

Pain was most perceived in shoulder back and neck region. Perceived pain increased with increase in load and with increase in time (Fig 9). Pain in shoulder (Fig 9A) and back (Fig 9B) was significantly different ($p<0.05$, ANOVA) for different load conditions. Pain perceived was higher for greater loads. From the first reporting of discomfort in the body, the pain was seldom reported to lower. Rather, it increased, gradually for lower loads but quickly escalating for higher loads.

This can be seen by the higher and steeper slopes of pain perception which level off towards end of 20-minute walk sessions.

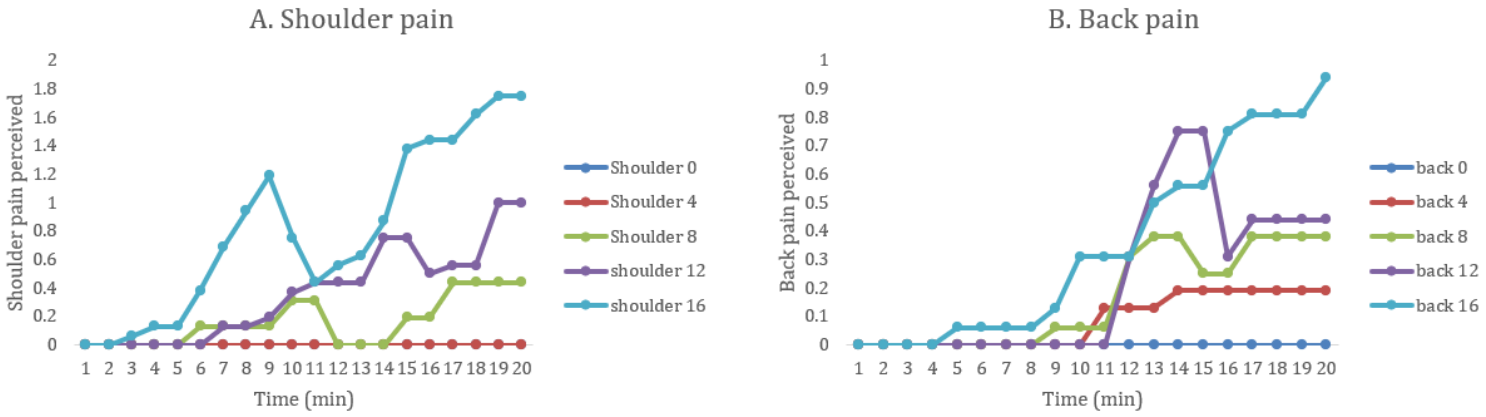

Figure 9: Perceived pain for different walks

Posture analysis (n=40 walks, n=1606 photographs):

Table 2: Postural angles for different walks among different BMI categories

GroupingSPSS		CVA	CRA	SA	HA	NF	HF	TF
N 0	Mean	43.1	143.1	50.0	32.2	46.9	83.7	6.7
	Std. Deviation	16.53	11.51	20.53	17.34	16.53	24.09	6.79
O 0	Mean	49.1	141.7	36.7	26.8	40.9	79.2	7.6
	Std. Deviation	12.85	9.88	13.76	14.55	12.85	19.28	4.92
N 4	Mean	50.9	139.6	46.6	28.7	39.1	79.5	0.1
	Std. Deviation	15.06	12.77	18.08	15.15	15.06	21.19	5.69
O 4	Mean	45.3	141.6	52.0	33.4	44.7	83.1	2.8
	Std. Deviation	28.88	12.84	19.27	16.11	28.88	33.17	4.72
N 8	Mean	44.7	140.8	50.9	34.3	45.3	84.5	3.3
	Std. Deviation	16.30	14.32	20.03	16.35	16.30	23.66	5.84
O 8	Mean	39.6	141.7	56.0	38.2	50.4	88.7	4.0
	Std. Deviation	15.95	14.79	19.02	16.52	15.95	24.85	4.18
N 12	Mean	51.2	140.0	51.3	27.4	38.8	78.8	1.5
	Std. Deviation	16.45	11.38	19.33	12.93	16.45	20.80	5.92

O 12	Mean	38.6	158.4	64.4	40.6	51.4	73.0	4.9
	Std. Deviation	37.18	158.92	23.31	15.56	37.18	161.85	2.95
N 16	Mean	43.0	138.6	42.9	34.3	47.0	88.4	4.4
	Std. Deviation	14.21	14.52	79.88	14.81	14.21	22.87	8.09
O 16	Mean	34.3	138.5	62.7	43.2	55.7	97.2	5.6
	Std. Deviation	15.92	15.18	20.36	17.23	15.92	24.95	3.88

All the angles are significantly different for different loads carried among normal and overweight/obese individuals ($p<0.05$, ANOVA). 8% load carriage in overweight participants demonstrated a steep decline in CVA deeming it to be unsuitable for overweight/obese. Lowest CVA was obtained for 16% loads in normal BMI participants deeming it to be unsuitable.

Proper posture is linked to better cognition [35]. Poorer postures are linked to musculo-skeletal discomfort [64]. Evaluation of cognitive parameters, pain and posture 12% load to be safe for normal BMI and 4% load carriage to be suitable for overweight/obese BMI.

Results for Objective 3:

Salivary assessment: Saliva was collected from the children before and after each walk and assessed for various oxidative stress parameters.

Fluid characteristics of saliva (n=80 samples):

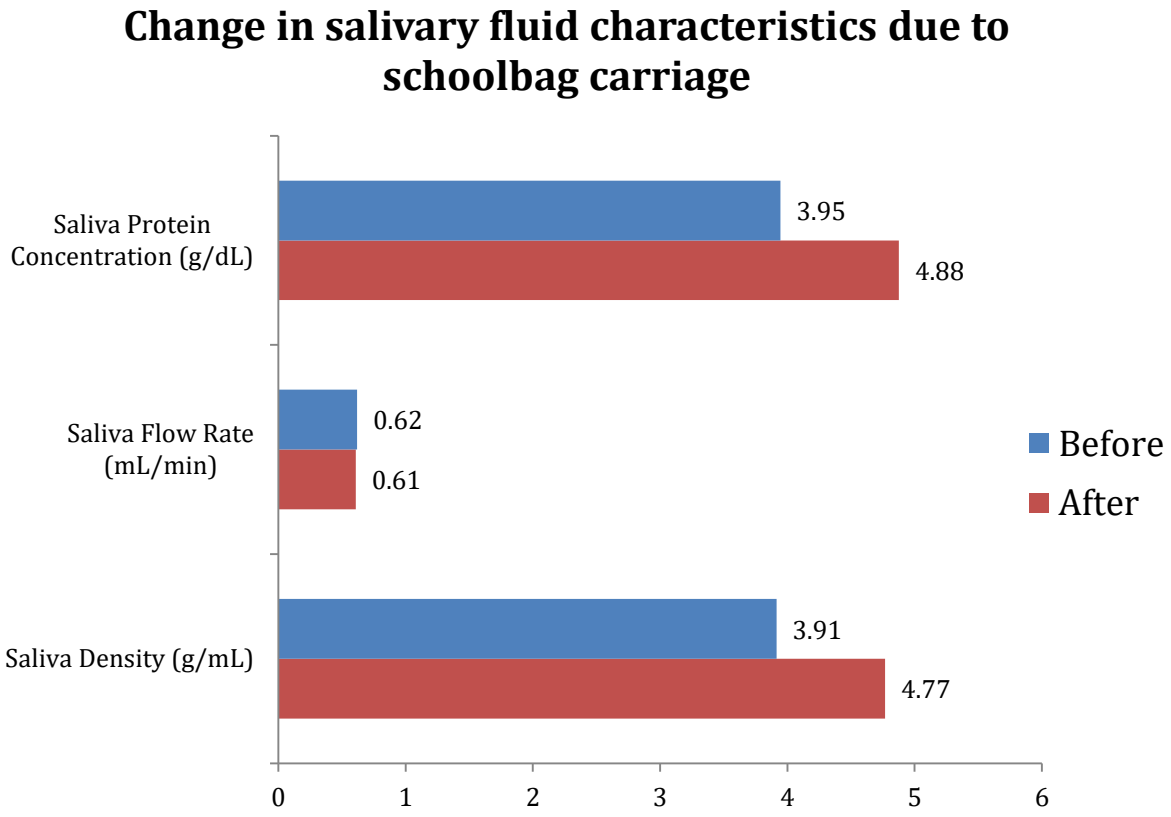

Figure 10: Fluid characteristics of saliva

Salivary protein concentration increased after walking with schoolbags. The salivary flow rate decreased (albeit minimally) while the salivary density increased (Fig 10). This indicated normal physiological response to a physical activity.

Ferric reducing antioxidant power (FRAP) assay (n=570 samples):

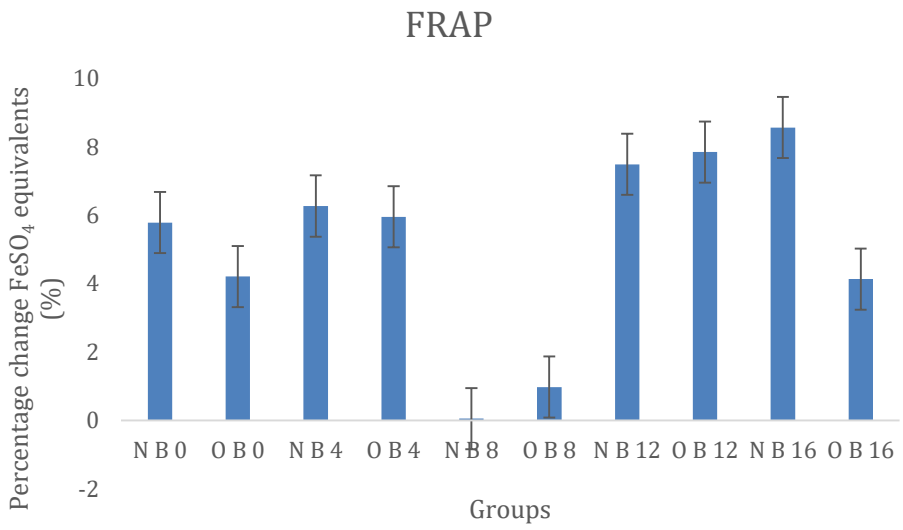

Figure 11: FRAP assay for different walks among the BMI categories. *NB0- percentage change after 0% walk in normal BMI, OB0- percentage change after 0% walk in overweight/obese BMI, NB4- percentage change after 4% walk in normal BMI, OB4- percentage change after 4% walk in overweight/obese BMI, NB8- percentage change after 8% walk in normal BMI, OB8- percentage change after 8% walk in overweight/obese BMI, NB12- percentage change after 12% walk in normal BMI, OB12- percentage change after 12% walk in overweight/obese BMI, NB16- percentage change after 16% walk in normal BMI, OB16- percentage change after 16% walk in overweight/obese BMI.*

The percentage increase in non-enzymatic antioxidant capacity of saliva was lowest for 8% load carriage in both normal and overweight/obese individuals.

Total antioxidant capacity (TAC) (n=450 samples):

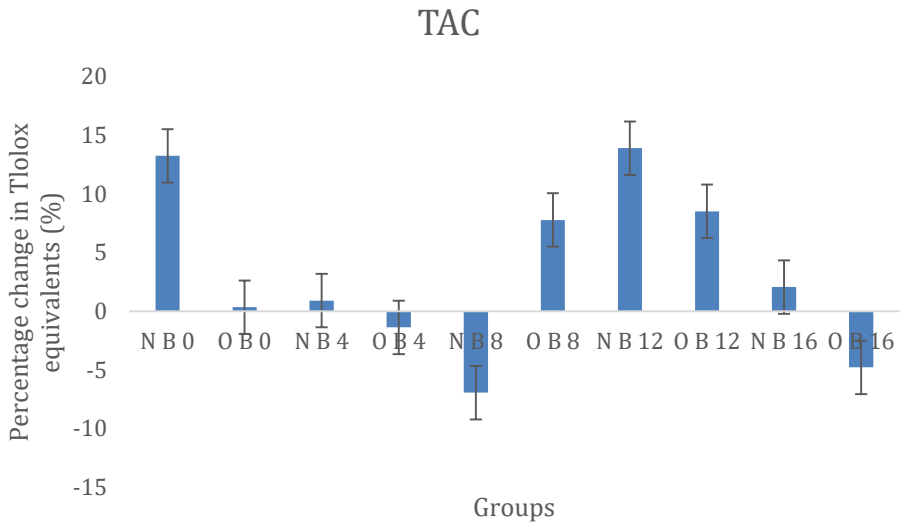

Figure 12: TAC assay for different walks among the BMI categories. *NB0- percentage change after 0% walk in normal BMI, OB0- percentage change after 0% walk in overweight/obese BMI, NB4- percentage change after 4% walk in normal BMI, OB4- percentage change after 4% walk in overweight/obese BMI, NB8- percentage change after 8% walk in normal BMI, OB8- percentage change after 8% walk in overweight/obese BMI, NB12- percentage change after 12% walk in normal BMI, OB12- percentage change after 12% walk in overweight/obese BMI, NB16- percentage change after 16% walk in normal BMI, OB16- percentage change after 16% walk in overweight/obese BMI.*

Greatest increase in total anti-oxidant capacity was observed after walking with 8% load in normal category participants (Fig 12). TAC increased for 4% and 16% load in overweight/obese category. 16% load carriage data is not complete as children (particularly those of the obese category) were unable to complete the walk for the 20-minute duration. TAC is a color reduction assay where decrease in absorbance indicated higher antioxidant capacity. TAC measured enzymatic as well as non-enzymatic antioxidant. As a pattern mismatch between antioxidant capacities were noted between Fig 11 and Fig 12, checking the enzymatic activity was deemed essential.

Glutathione peroxidase (GPx) activity (n=80 samples):

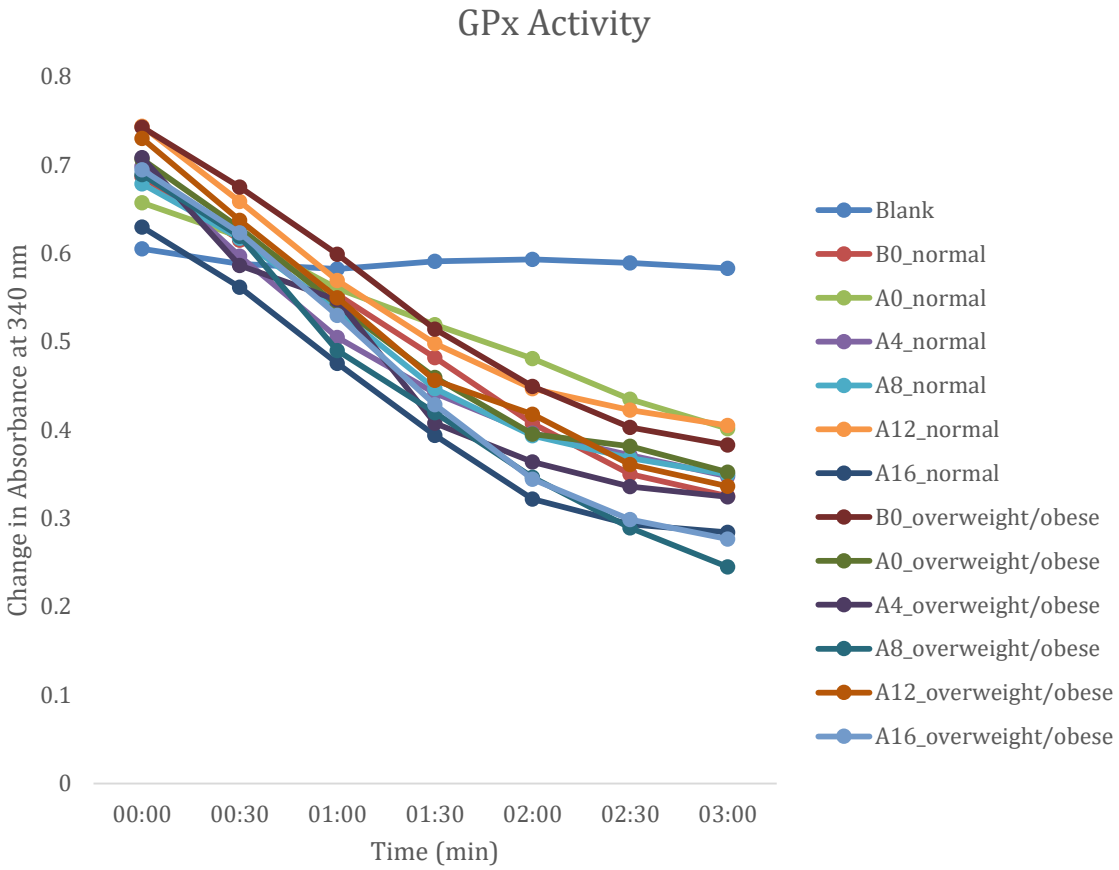

Figure 13: GPx activity for different walks among the BMI categories

GPx activity is essential to combat oxidative stress. Lowest activity was found after 16% walks in overweight/obese subjects, while the highest was observed for normal category subjects after walking without a schoolbag (Fig 13). Calculated GPx activity have been represented in Table 3.

Table 3: GPx activity before and after different walking conditions

GPx Activity (nmol NADPH/ min/ml)	Blank	B0_normal	A0_normal	A4_normal	A8_normal	A12_normal	A16_normal
	3.7	21.41	15.64	31.15	23.07	28.05	24.76
		B0_overweight/obese	A0_overweight/obese	A4_overweight/obese	A8_overweight/obese	A12_overweight/obese	A16_overweight/obese
		23.15	26.45	25.88	32.05	28.98	26.53

From evaluation of antioxidant capacity and GPx activity, 8% and 4% load carriage were deemed to be safe for normal and overweight/obese BMI respectively.

Thiobarbituric acid-reactive substances (TBARS) (n=450 samples):

TBARs estimates malondialdehyde, a by-product of lipid peroxidation that occurs due to generation of ROS in the body.

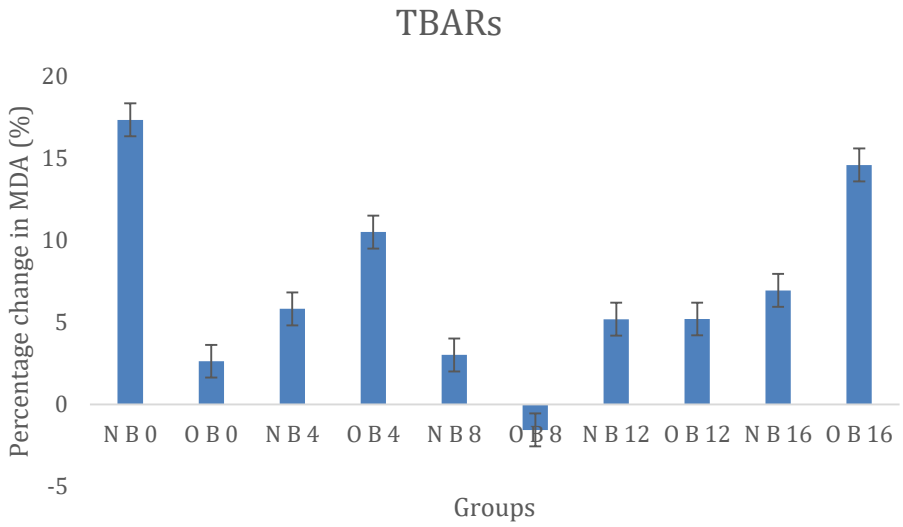

Figure 14: TBARs assay for different walks among the BMI categories. *NB0- percentage change after 0% walk in normal BMI, OB0- percentage change after 0% walk in overweight/obese BMI, NB4- percentage change after 4% walk in normal BMI, OB4- percentage change after 4% walk in overweight/obese BMI, NB8- percentage change after 8% walk in normal BMI, OB8- percentage change after 8% walk in overweight/obese BMI, NB12- percentage change after 12% walk in normal BMI, OB12- percentage change after 12% walk in overweight/obese BMI, NB16- percentage change after 16% walk in normal BMI, OB16- percentage change after 16% walk in overweight/obese BMI.*

Highest oxidative stress damage was found after 16% walks in overweight/obese subjects (Fig 14) but the greatest increase (not the absolute values) was found after 0% load carriage in normal BMI category.

Griess reaction assay (n=450 samples):

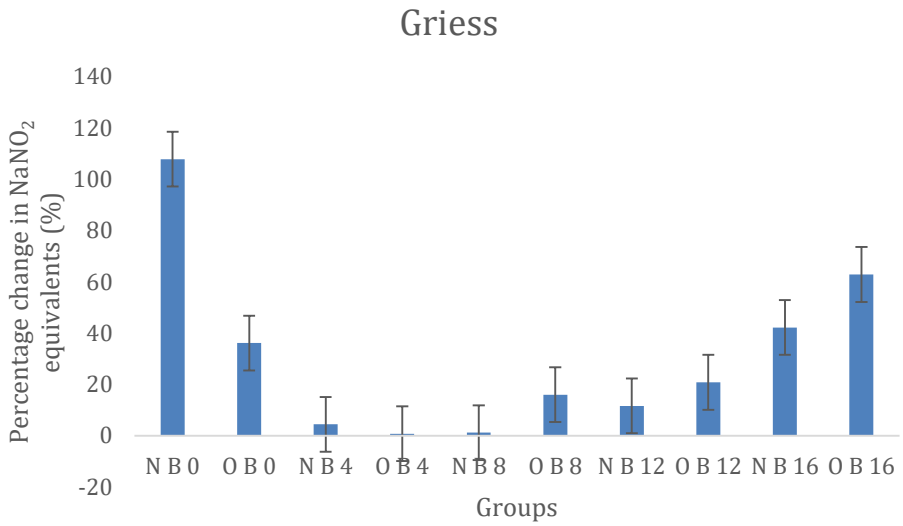

Figure 15: Griess assay for different walks among the BMI categories. *NB0- percentage change after 0% walk in normal BMI, OB0- percentage change after 0% walk in overweight/obese BMI, NB4- percentage change after 4% walk in normal BMI, OB4- percentage change after 4% walk in overweight/obese BMI, NB8- percentage change after 8% walk in normal BMI, OB8- percentage change after 8% walk in overweight/obese BMI, NB12- percentage change after 12% walk in normal BMI, OB12- percentage change after 12% walk in overweight/obese BMI, NB16- percentage change after 16% walk in normal BMI, OB16- percentage change after 16% walk in overweight/obese BMI.*

Highest NO production was observed in normal BMI individuals when walking without load indicating proper regulation of microcirculation (Fig 15). 8% load for normal BMI and 4% load overweight/obese BMI indicated lowest stress.

Saville reaction coupled to Griess assay to determine Reactive Nitrogen Species (RNS) (n=450 samples):

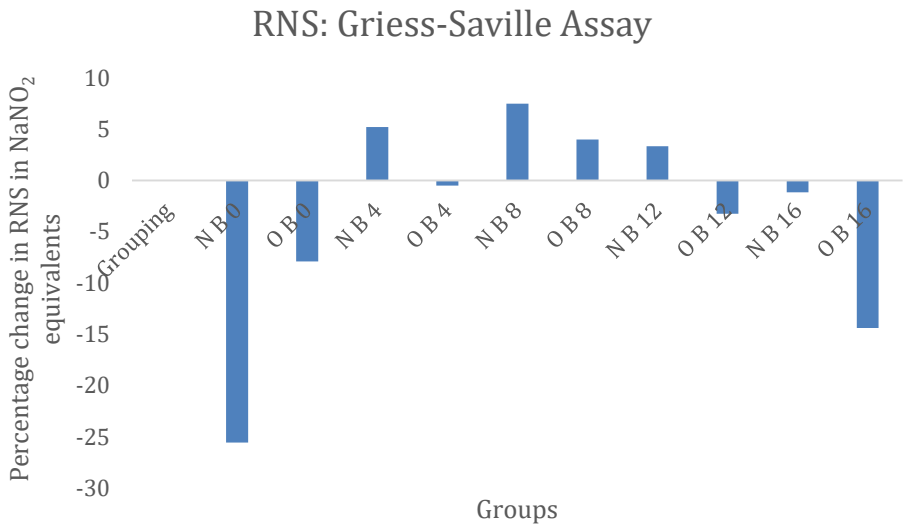

Figure 16: Griess-Saville assay for different walks among the BMI categories. *NB0- percentage change after 0% walk in normal BMI, OB0- percentage change after 0% walk in overweight/obese BMI, NB4- percentage change after 4% walk in normal BMI, OB4- percentage change after 4% walk in overweight/obese BMI, NB8- percentage change after 8% walk in normal BMI, OB8- percentage change after 8% walk in overweight/obese BMI, NB12- percentage change after 12% walk in normal BMI, OB12- percentage change after 12% walk in overweight/obese BMI, NB16- percentage change after 16% walk in normal BMI, OB16- percentage change after 16% walk in overweight/obese BMI.*

Highest RNS was found after 8% load carriage in normal BMI category individuals (Fig 16).

Comet Assay:

Comet assay done to evaluate DNA damage due to ROS (if any) for the physical activity of schoolbag carriage. No changes were observed after walks compared to before walks ~~(Fig 17)~~. In many samples comet tails were visible. This indicates DNA damage in the cells present in saliva due to other external reasons not addressed in this work.

~~Figure 17: Comet assay.~~

D*aily antioxidant intake* (n=300 walks):

Diet survey was done on each day of the walk by 24-h recall method. Once the food items were obtained, the commonly found antioxidants in those items were listed and antioxidant intake was evaluated. The results have been tabulated in Table 4.

Table 4: Dietary antioxidant intake by 24-h recall method

BMI Category		Vitamin C/ ascorbic acid (mg)	Vitamin A/ retinol (ug)	Vitamin E/ tocopherol (mg)	Lutein (ug)	Lycopene (ug)	Cryptoxanthins (ug)	Beta-carotene (ug)	Copper (mg)	Manganese (mg)	Selenium (mg)	Zinc (mg)	Catechin (mg)	Polyphenol (mg)
N	Mean	23.1	22.1	0.5	300.5	130.4	20.8	369.7	0.4	1.4	16.5	1.7	0.2	48.5
	Std. Deviation	45.92	199.39	2.04	1285.32	777.34	245.06	1494.85	0.49	6.54	32.86	2.96	0.93	99.66
O	Mean	21.5	25.6	0.5	175.1	106.8	19.8	244.7	0.4	1.0	17.9	1.8	0.1	42.7

	Std. Deviation	46.72	90.41	1.07	862.57	683.36	213.60	1243.77	0.52	3.09	33.24	3.33	0.97	84.87

Among the overweight and normal participants, antioxidants beta-carotene (ug) and catechin (mg) intake were found to differ significantly ($p<0.05$, ANOVA). Except Retinol, selenium and Zinc, all other antioxidants commonly found in the food were present in greater amounts in normal subjects compared to overweight/obese individuals (Table 4).

VI. Discussion

Schoolbag carriage is one of the most prevalent physical activities seen in children. Heavy schoolbags can have a myriad of physiological actions, mostly derogatory in nature. While pain reports due to heavy schoolbags are common [65,66] there are lacunae in research related to this physical activity. The existing guidelines does not protect children from the ill-effects of carrying heavy schoolbags and new guidelines suited for all must be framed based on relevant data.

A multitude of research has established that the physiological response to a physical activity is a function of one's BMI [14,67]. Therefore, it is essential that schoolbag carriage must be evaluated with respect to BMI. Evaluation of cardio-pulmonary parameters is the fulcrum of investigating a physical activity. Comparison of heart rates during schoolbag carriage did not portray any significant relationship with load of carriage in participants. This matched with prior reports [6]. Closer inspection revealed that heart rates increase in normal BMI participants linearly for 0, 4 and 8% loads, but thereafter it decreased. This may be due to the reason that a few walks remained incomplete (Fig 3) with higher load carriage and therefore the heart rate enhancement, an indication of exhaustion was not achieved. Heart rate decreased in overweight/obese BMI category almost linearly through increasing bag weights (Fig 3). This could also be attributed to incomplete walks. The heart rates obtained during loaded backpacks carriage, correspond to greater than 55% of the maximal heart rates in both the BMI categories thus establishing schoolbag carriage as a moderate intensity physical activity [68].

The pulmonary parameters studied were all significantly higher in overweight/obese individuals (Fig 4). Tidal volume is known to increase with moderate exercise [69]. It is reported that elevation in tidal volume during physical activity is a normal physiological response in obese individuals to fulfil oxygen demand in the body [70]. Obesity also stipulates a higher pulmonary ventilation for

a given workload [71]. Maximal oxygen uptake was also reportedly higher in overweight/obese individuals during physical activity [72] and even at rest [14].

Breathing pattern analysis gives new insights to the pulmonary response during schoolbag carriage (Fig 4). It is interesting to note that while the total time for each breath decreased linearly for normal BMI participants, the same increased almost linearly for overweight/obese participants. However, the absolute time for each breath, inspiratory and expiratory, was lower in case of overweight/obese participants. It is reported that obese individuals increase their respiratory rates during exercise to compensate for elevated oxygen demand in the body [70]. While the average energy expenditure does not show stark difference in case of normal BMI category participants, it decreased linearly with increase in bag weight for overweight/obese individuals (Fig 6). This could be due to incomplete walks and lower speeds adopted during heavy backpack carriage (Fig 7). The muscles in our body work at "minimal effort criteria" where increase in backpack load is compensated by a decrease in adopted speed [7].

Reaction time was seen to decrease or improve in the participants after walking without schoolbags (Fig 8A). Simple walking is equivalent to a structured physical activity or exercise. Improvement in cognitive parameters after exercise is well-reported [34,73]. The handgrip strength also decreased after walking with schoolbags (Fig 8B). This reflects fatigability induced due to heavy schoolbags. Similar results were obtained for CFFF (Fig 8C) which improved when walking without load and worsened when walking with schoolbags.

Many reports suggest increased pain in shoulder and back region due to schoolbag carriage [74–76]. This study also observed the same. However, the timeline representation of pain perception throughout the physical activity of schoolbag carriage is a unique feature of this study. It can be seen from Fig 9 that although both shoulder and back pain has highest intensities and prior occurrence for 16% of bodyweight load carriage, the onset of shoulder pain precedes that of back pain. On the contrary, while shoulder pain is not reported for 0 and 4% load carriage back pain is present also for 4% load carriage even if in low amount. This indicates that musculo-skeletal pain during schoolbag carriage might have acute effect on the shoulder but chronic effect at the back.

Posture analysis (Table 2) revealed that lowest cranio-vertebral angle pertaining to poorest posture was adopted by overweight/obese participants during 16% load of bodyweight walking conditions. Same was seen for cranio-rotation angle. Neck and head flexion was highest for overweight/obese subjects during walking with 16% load of bodyweight. This is in accordance with previous studies that suggest increase in forward head posture, forward lean occurs due to heavy backpacks [77].

The cranio-vertebral angle is the mainly focused upon for detection of forward head posture. CVA lower than 60^{o} is the clinical diagnosis for forward head posture. 8% load carriage in overweight participants witnessed a steep decline in CVA deeming it to be unsuitable for overweight/obese.

Physical activity activates the sympathetic nervous system [78]. Sympathetic innervations to the parotid gland which is the largest salivary gland affects the protein content of saliva [79] which might be the reason for the increase in salivary protein concentration (Fig 10). Decreased salivary flow rate may also be attributed to sympathetic activation causing vasoconstriction [80]. Salivary density changes in response to decreased flow rate and increased protein concentration. Increase in salivary density and decreased flow rate [81,82] due to physical activity has been previously reported.

While FRAP assay (Fig 11) detects non-enzymatic antioxidant capacity, TAC assay (Fig 12) detects both enzymatic and non-enzymatic antioxidant capacity. Increase in non-enzymatic activity corresponds to lesser total antioxidant capacity for lower loads. Higher loads show increase in non-enzymatic activity as well as decrease in total antioxidant capacity indicating depletion of enzymatic antioxidants, during higher loads of schoolbag carriage. Evaluating glutathione peroxidase enzyme activity levels at 0% load carriage in normal BMI category had highest activity whereas 16% load carriage in normal had lowest enzymatic activity (Fig 13). By-product of lipid peroxidation was obtained in high amount for 16% load in overweight/obese BMI participants (Fig 14). These results correspond to existing reports that demonstrated an increase in ROS and its reactive by-products on physical activity [39,83], although these parameters have never been evaluated in children before with respect to school bag carriage.

Reactive oxygen species when in large quantities, can react with Nitric Oxide forming Reactive nitrogen species. NO is a potent vasodilator and is needed physiologically to maintain the demands of oxygen supply. NO decreased gradually from 0 to 8% load and increased till 16% load. NO was measured by Griess assay. When coupled to Saville assay it can, provide information about reactive nitrogen species. The graphs for Griess Assay and Saville-coupled assay RNS are inversions of each other. Biochemical analyzes shows adaptive response of the body to oxidative stress in normal BMI participants for 8% loads. Most similar to this scenario was 4% load carriage in case of overweight/obese BMI. Comet assay did not show any DNA damage. This matches to prior reports suggesting no DNA damage due to physical activity by comet assay [84].

Dietary intake of antioxidants can be vitamins or minerals which are components of anti-oxidant enzymes [85]. Based on the 24-hr dietary recall, the difference in dietary antioxidant intake between overweight/obese and normal category children are not very palpable.

VII. Conclusion

Table 5: Summary of conclusions from parameters of the study

Parameters of the study	Conclusions drawn/safe load limits
Anthropometry and body composition analysis	The participants were divided into various BMI categories
Cardiac response	Normal BMI- 8% Overweight/obese BMI- 0%
Breathing pattern	Normal BMI- 4% Overweight/obese BMI- 4%
Pulmonary response	Disadvantageous for higher BMI
Cognitive parameters	Improves only for no load
Perceived pain	Shoulder- acute effects Back- chronic effects
Posture analysis	Normal BMI- 12% Overweight/obese BMI- 4%
Antioxidant capacity	Normal BMI- 8% Overweight/obese BMI- 4%
NO production	Normal BMI- 16% Overweight/obese BMI- 16%
Reactive Nitrogen Species	Normal BMI- 4% Overweight/obese BMI- 4%
Comet assay	No observable DNA damage (in 20-min)
Dietary Antioxidant Intake	Similar for BMI categories

The physical activity of schoolbag carriage is markedly different for undernutrition/ normal and overweight/obese BMI categories. The recommendations on safe load limits must be inclusive of a child's BMI.

Recommendations: The schoolbag load for underweight/normal BMI children should not exceed 8% load of body weight. The schoolbag load for overweight/obese BMI children should not exceed 4% load of body weight.

VIII. Significance of the study

Orthopedic issues due to heavy schoolbag carriage is common and a growing concern in India. With the entire emergent population of the nation at risk, this work is of vital importance to highlight the seriousness of the problem and initiate interventions needed for effective improvement of well-being in children.

IX. Future Directions

This study involving physical activity in male children can be extrapolated to the female population besides being applied to other work sectors involving the physical activity of load carriage such as porters, manual material handlers, laborers in the unorganized work sectors such as brick carriers. This study may also be investigated in various work sectors involving postural stress.

X. References

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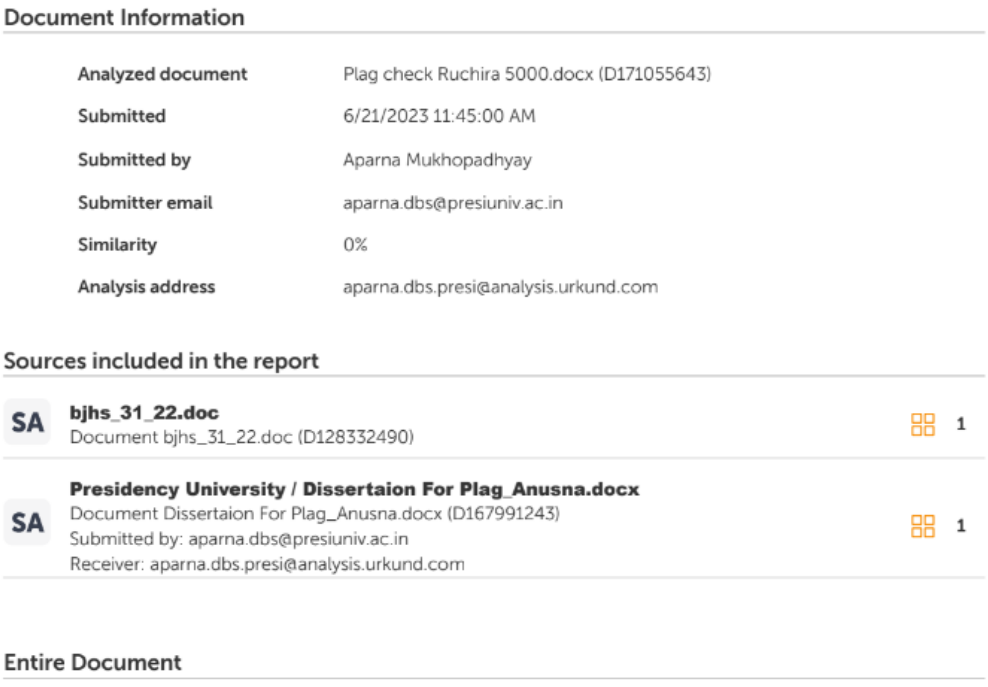
XI. Plagiarism Certificate



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Paper Presentation Certificate

This is to certify that Prof./Dr./Shri/Smt. Ruchira Mukherjee

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has presented a Paper (Oral/Poster) entitled "Protective principles aged 13-15 years" in the Section of Medical Sciences including Physiology during the 106th Indian Science Congress held at Lovely Professional University, Phagwara, Jalandhar from January 3 to 7, 2019.

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IIT Guwahati, India

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OF PARTICIPATION

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Percentage Change in Reaction Time Can Predict Respiratory Quotient during Light Weight Schoolbag Carriage

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Abstract

While structured physical activity improves cardio-pulmonary parameters and Reaction Time (RT), heavy weight schoolbag carriage is detrimental. Schoolbag carriage may have either consequence. The purpose of this study is to explore the consequences of heavy and light weighing schoolbags on cardio-pulmonary parameters and RT. Healthy male participants (10-15 years) carrying schoolbags- 0%, 4%, 8%, 12%, 16% load of bodyweight walked (20-minutes) for 5 times each. For each of the 30 participants, during walks, COSMED k4b2 measured heart rate (HR), respiratory quotient (R), total energy expenditure (EEtot) and number of steps taken. Ruler-drop-test marked RT before and after each walk. RT improved after walking with schoolbags weighing 0%, 4% of bodyweight. RT didn't improve for 8%, 12% carriage, worsened for 16% load carriage. HR and EEtot showed proportionality ($r=0.24$, $p<0.05$), R correlated positively to percentage change in RT ($r=0.24$, $p<0.05$) and inversely to number of steps taken ($r=-0.40$, $p<0.01$). Percentage change in RT could significantly predict R ($R=1.223+0.028$(Percentage RT change)). Respiratory quotient can predict whether or not reaction time worsens for 20-minutes schoolbag carriage as per Receiver Operating Characteristic (ROC) curve (Area Under Curve (AUC)=0.668, 95% confidence interval: 0.558-0.779, $p<0.01$). Carrying light-weight schoolbags (4% of bodyweight) for 20-minutes is beneficial, but heavy-backpack carriage effectuates adverse cardio-pulmonary response and higher RT.

Keywords: COSMED k4b2; Ruler drop test; ROC curve; Heart rate; Walking speed

Abbreviations: HR: Heart Rate; R: Respiratory Quotient; EEtot: Total Energy Expenditure; RT: Reaction Time; U: Predicted Upper Limit; L: Predicted Lower Limit; CI: Confidence Interval; AUC: Area Under the Curve; ROC curve: Receiver Operating Characteristic curve.

Introduction

Each school-going child, irrespective of the background they belong to carry schoolbags. School curriculum demands heavy backpacks and absence of lockers mandates schoolbag carriage for children. The physiological cost of carrying heavy schoolbags is enormous and heavily documented, most common of which is low back pain, scoliosis, change in posture, and change in muscular activity [1-3]. Schoolchildren being in the expeditious growth and development phase are more vulnerable to the ill effects of the aforementioned musculo-skeletal symptoms [4]. Moreover, pain in childhood and adolescence persists even in adulthood [5] vitiating the emergent population.

Besides the musculo-skeletal effects, backpack carriage has cardio-respiratory consequences. Carrying heavier backpacks are denoted to cause increased heart rate, energy expenditure [6] and decreased pulmonary ventilation [7] indicating less oxygen availability. As bodily movement involving energy expenditure is termed as a physical activity which when performed regularly for a fixed duration of time,

Original Article

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Alterations of hand muscle strength in children due to schoolbag carriage

Ruchira Mukherjee, Koumi Dutta[1], Devashish Sen, Subhashis Sahu[1], Aparna Mukhopadhyay

Abstract:

BACKGROUND: Heavy schoolbag carriage induces pain and fatigue in children. It can alter the handgrip strength (HGS) in children – an important parameter given that most activities in school curriculum require hand dexterity. The purpose of this study is to explore if and how schoolbag carriage influence HGS in children.

MATERIALS AND METHODS: Twenty-five healthy male participants (10–15 years) walked without schoolbag (0% load of bodyweight) or with schoolbags (weighing 4%, 8%, 12%, or 16% of their bodyweight) for 20 min on plane surface at preferred pace. The number of steps taken during walk was measured using pedometer. HGS was measured before and after each walk using dynamometer. The heart rate during walk was measured using Polar HR monitor. Pain occurrence in the entire body was mapped.

RESULTS: HGS averaged for both hand decreased from 17.8 (±6.72) kg to 17.3 (±6.28) kg after 20-min walk (P = 0.033, paired sample t-test). The adopted speed and heart rate was higher when carrying a schoolbag but it portrayed no significant association with HGS. Occurrence of shoulder pain significantly associated with increasing in HGS of right hand after walking (Phi coefficient = 0.21[P = 0.030]). If shoulder pain was perceived during walk, there was a 2.5 times higher likelihood that the participants' HGS for right hand increased (odd's ratio = 2.515, 95% confidence interval = 1.086–5.825).

CONCLUSION: Schoolbag carriage reduces HGS in children. Therefore, performing upper body conditioning exercises may help ameliorate the ill effects of heavy backpack carriage.

Keywords:

Children, dynamometer, odd's ratio, Phi coefficient, physical activity

Education in India follows a "textbook culture" where prescribed textbooks for each subject hold central place in the system.[1] Carrying numerous textbooks increase the weight of schoolbags. The recommended schoolbag load, 10%–15% of bodyweight,[2] is seldom adhered to[3] and reportedly has derogatory physiological effects.[4,5] Hence, it is essential to explore schoolbag carriage with loads lesser than, within, and above this 10%–15% limit. Heavy schoolbag carriage may culminate in the development of low-back pain, changed spinal curvature, and a multitude of musculoskeletal symptoms.[6-8]

Schoolbag carriage causes pain in upper body parts such as neck, back, and shoulders,[9] also, prolonged carriage can induce fatigue.[10] The physical activity of schoolbag carriage for 30 min induced fatigue in 51% of the participants.[11] Fatigability and severity of muscle fatigue can be assessed by repeated measurements of handgrip strength (HGS).[12] It has been reported that significantly reduced HGS may indicate muscle and fatigue-related symptoms.[13]

HGS is not only a measure of upper body strength but also a screening tool for

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Investigating the Facets of Physical Activity Related to Schoolbag Carriage- Highlighting the Lacunae that Exists

Ruchira Mukherjee [α], Rajarshi Chanda [α], Devashish Sen [ρ], Subhashis Sahu [Ω] & Aparna Mukhopadhyay [¥]

Abstract- **Schoolbag carriage is the most common physical activity performed among school children. The relevant scientific explorations in this regard, has entailed investigation of consequent pain, muscle activity and related fatigue. General fatigue reportedly alters the sensation of thirst and salivary viscosity. Fatigue, thirst and saliva viscosity is also related to neurological performance and alacrity. Moreover, general fatigue is also reflected in eye muscles and visual processing is an integral part of learning in school children. The purpose of this review is to explore these facets of physical activity in relation to schoolbag carriage and in the process extracting the lacunae that exists in exploring the physical activity schoolbag carriage.**

Keywords: schoolbag carriage, saliva viscosity, thirst, cognition, fatigue, critical flicker fusion frequency (CFFF).

I. Introduction

Every school-going child, irrespective of their social standing and/or how sedentary a lifestyle they lead, has the physical activity of schoolbag carriage in common. In India, absence of lockers and a very demanding school curriculum, not only makes the schoolbags very heavy, but also its carriage mandatory. It is of utmost importance to explore all facets and effects of this physical activity, given that all subsequent activities within the school curriculum begins after at least a single bout of schoolbag carriage required to reach the classrooms from home.

The World Health Organization (WHO) defines physical activity as energy expended in any form by the skeletal muscles. Physical activity not only improve one's overall well-being, but also enhances thinking, learning and judgment skills[1]. Given that these skills are a focal point of school education, this further bolsters the importance of schoolbag carriage. This particular physical activity should therefore be explored not only in terms of skeletal muscle response but also in terms of cognition and motor ability.

The impact of physical activity in its varying intensities have been well documented[2,3]. Schoolbag carriage can be a moderate or high intensity physical activity based on the amount of load being carried [4]. Intense physical activity is generally characterized with fatigue[5] and schoolbag carriage related fatigue has been previously reported[6]. Overall fatigue can be reflected in eye muscles and be quantified using Critical Flicker Fusion Frequency (CFFF)[7]. CFFF is vital for children given that a major portion of school curriculum entails viewing the blackboard or projector screen. Fatigue resultant from schoolbag carriage to reach the school may also interfere with concentration of a child subsequently affecting scholastic performance.

Apart from overall fatigue being reflected in the eye muscles, increased heartbeat, increased thirst and saliva viscosity[8] are also characteristic of physical activity. Increase in sensation of thirst is observed as the intensity of physical activity increases[9]. Increased thirst is delineated to increase saliva viscosity[5]. Reportedly, thirst and physical activity together cause changes in neurological alacrity[10]. Cognitive and motor performance is seen to be impacted due to fatigue and thirst[11,12]. Scrutinizing the physical activity of schoolbag carriage is hence incomplete without exploring its effect on thirst, salivary viscosity and cognition.

The effect of physical activity on all the aforementioned factors-fatigue reflected in CFFF, thirst, cognitive and motor performances are inter-related, co-dependent and modulate each other. Given the importance of fatigue on the ability to focus on academic curriculum and the importance of cognition in children, investigating the influence of the physical activity of schoolbag carriage and its intensity on these parameters can be insightful and is topical.

II. Methodology

Numerous papers were reviewed relevant to the topic in hand and arranged into subheads that are included in the scope of this particular review. Some data were not available or were not apparent and unclear, such studies were excluded.

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Certificates of ethical clearances

Presidency University
Kolkata

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Institutional Ethical Committee (IEC) For Research on Human Participants (ICMR Guidelines)

December 17, 2018

REF: ....PU/IEC(H)/CL/A01/2018

To
Dr. Aparna Mukhopadhyay
Assistant Professor
Dept. of Life Sciences
Presidency University, Kolkata

Sub: Approval to conduct study entitled "Evaluation of cardio-respiratory and oxidative stress parameters among normal weight and overweight/ obese urban school children due to mandatory load carriage in West Bengal, India"

Dear Dr. Mukhopadhyay,

As per our Institutional Ethical Committee for Human research, Presidency University, Kolkata, your proposal entitled **"Evaluation of cardio-respiratory and oxidative stress parameters among normal weight and overweight/ obese urban school children due to mandatory load carriage in West Bengal, India"** has been received and as per discussion with the members, clearance is hereby given to you.

You are requested to go along with the project in its present form.

The committee expects that any amendments to the study protocol, informed consent documents and other relevant documents would be brought to the notice of IEC (H), PU.

With best wishes,

17/12/18

Member Secretary
IEC - (Human) for research
Presidency University

Member Secretary
Institutional Ethical Committee (Human)
Presidency University, Kolkata.

BMI-for-age BOYS
5 to 19 years (z-scores)

World Health Organization

Year: Month	Months	-3 SD	-2 SD	-1 SD	Median	1 SD	2 SD	3 SD
10: 1	121	12.8	13.8	15.0	16.5	18.5	21.5	26.2
10: 2	122	12.8	13.8	15.0	16.5	18.6	21.6	26.4
10: 3	123	12.8	13.8	15.0	16.6	18.6	21.7	26.6
10: 4	124	12.9	13.8	15.0	16.6	18.7	21.7	26.7
10: 5	125	12.9	13.9	15.1	16.6	18.8	21.8	26.9
10: 6	126	12.9	13.9	15.1	16.7	18.8	21.9	27.0
10: 7	127	12.9	13.9	15.1	16.7	18.9	22.0	27.2
10: 8	128	13.0	13.9	15.2	16.8	18.9	22.1	27.4
10: 9	129	13.0	14.0	15.2	16.8	19.0	22.2	27.5
10: 10	130	13.0	14.0	15.2	16.9	19.0	22.3	27.7
10: 11	131	13.0	14.0	15.3	16.9	19.1	22.4	27.9
11: 0	132	13.1	14.1	15.3	16.9	19.2	22.5	28.0
11: 1	133	13.1	14.1	15.3	17.0	19.2	22.5	28.2
11: 2	134	13.1	14.1	15.4	17.0	19.3	22.6	28.4
11: 3	135	13.1	14.1	15.4	17.1	19.3	22.7	28.5
11: 4	136	13.2	14.2	15.5	17.1	19.4	22.8	28.7
11: 5	137	13.2	14.2	15.5	17.2	19.5	22.9	28.8
11: 6	138	13.2	14.2	15.5	17.2	19.5	23.0	29.0
11: 7	139	13.2	14.3	15.6	17.3	19.6	23.1	29.2
11: 8	140	13.3	14.3	15.6	17.3	19.7	23.2	29.3
11: 9	141	13.3	14.3	15.7	17.4	19.7	23.3	29.5
11: 10	142	13.3	14.4	15.7	17.4	19.8	23.4	29.6
11: 11	143	13.4	14.4	15.7	17.5	19.9	23.5	29.8
12: 0	144	13.4	14.5	15.8	17.5	19.9	23.6	30.0
12: 1	145	13.4	14.5	15.8	17.6	20.0	23.7	30.1
12: 2	146	13.5	14.5	15.9	17.6	20.1	23.8	30.3
12: 3	147	13.5	14.6	15.9	17.7	20.2	23.9	30.4
12: 4	148	13.5	14.6	16.0	17.8	20.2	24.0	30.6
12: 5	149	13.6	14.6	16.0	17.8	20.3	24.1	30.7
12: 6	150	13.6	14.7	16.1	17.9	20.4	24.2	30.9

BMI-for-age BOYS
5 to 19 years (z-scores)

World Health Organization

Year: Month	Months	-3 SD	-2 SD	-1 SD	Median	1 SD	2 SD	3 SD
12: 7	151	13.6	14.7	16.1	17.9	20.4	24.3	31.0
12: 8	152	13.7	14.8	16.2	18.0	20.5	24.4	31.1
12: 9	153	13.7	14.8	16.2	18.0	20.6	24.5	31.3
12: 10	154	13.7	14.8	16.3	18.1	20.7	24.6	31.4
12: 11	155	13.8	14.9	16.3	18.2	20.8	24.7	31.6
13: 0	156	13.8	14.9	16.4	18.2	20.8	24.8	31.7
13: 1	157	13.8	15.0	16.4	18.3	20.9	24.9	31.8
13: 2	158	13.9	15.0	16.5	18.4	21.0	25.0	31.9
13: 3	159	13.9	15.1	16.5	18.4	21.1	25.1	32.1
13: 4	160	14.0	15.1	16.6	18.5	21.1	25.2	32.2
13: 5	161	14.0	15.2	16.6	18.6	21.2	25.2	32.3
13: 6	162	14.0	15.2	16.7	18.6	21.3	25.3	32.4
13: 7	163	14.1	15.2	16.7	18.7	21.4	25.4	32.6
13: 8	164	14.1	15.3	16.8	18.7	21.5	25.5	32.7
13: 9	165	14.1	15.3	16.8	18.8	21.5	25.6	32.8
13: 10	166	14.2	15.4	16.9	18.9	21.6	25.7	32.9
13: 11	167	14.2	15.4	17.0	18.9	21.7	25.8	33.0
14: 0	168	14.3	15.5	17.0	19.0	21.8	25.9	33.1
14: 1	169	14.3	15.5	17.1	19.1	21.8	26.0	33.2
14: 2	170	14.3	15.6	17.1	19.1	21.9	26.1	33.3
14: 3	171	14.4	15.6	17.2	19.2	22.0	26.2	33.4
14: 4	172	14.4	15.7	17.2	19.3	22.1	26.3	33.5
14: 5	173	14.5	15.7	17.3	19.3	22.2	26.4	33.5
14: 6	174	14.5	15.7	17.3	19.4	22.2	26.5	33.6
14: 7	175	14.5	15.8	17.4	19.5	22.3	26.5	33.7
14: 8	176	14.6	15.8	17.4	19.5	22.4	26.6	33.8
14: 9	177	14.6	15.9	17.5	19.6	22.5	26.7	33.9
14: 10	178	14.6	15.9	17.5	19.6	22.5	26.8	33.9
14: 11	179	14.7	16.0	17.6	19.7	22.6	26.9	34.0
15: 0	180	14.7	16.0	17.6	19.8	22.7	27.0	34.1

BMI-for-age BOYS
5 to 19 years (z-scores)

World Health Organization

Year: Month	Months	-3 SD	-2 SD	-1 SD	Median	1 SD	2 SD	3 SD
15: 1	181	14.7	16.1	17.7	19.8	22.8	27.1	34.1
15: 2	182	14.8	16.1	17.8	19.9	22.8	27.1	34.2
15: 3	183	14.8	16.1	17.8	20.0	22.9	27.2	34.3
15: 4	184	14.8	16.2	17.9	20.0	23.0	27.3	34.3
15: 5	185	14.9	16.2	17.9	20.1	23.0	27.4	34.4
15: 6	186	14.9	16.3	18.0	20.1	23.1	27.4	34.5
15: 7	187	15.0	16.3	18.0	20.2	23.2	27.5	34.5
15: 8	188	15.0	16.3	18.1	20.3	23.3	27.6	34.6
15: 9	189	15.0	16.4	18.1	20.3	23.3	27.7	34.6
15: 10	190	15.0	16.4	18.2	20.4	23.4	27.7	34.7
15: 11	191	15.1	16.5	18.2	20.4	23.5	27.8	34.7
16: 0	192	15.1	16.5	18.2	20.5	23.5	27.9	34.8
16: 1	193	15.1	16.5	18.3	20.6	23.6	27.9	34.8
16: 2	194	15.2	16.6	18.3	20.6	23.7	28.0	34.8
16: 3	195	15.2	16.6	18.4	20.7	23.7	28.1	34.9
16: 4	196	15.2	16.7	18.4	20.7	23.8	28.1	34.9
16: 5	197	15.3	16.7	18.5	20.8	23.8	28.2	35.0
16: 6	198	15.3	16.7	18.5	20.8	23.9	28.3	35.0
16: 7	199	15.3	16.8	18.6	20.9	24.0	28.3	35.0
16: 8	200	15.3	16.8	18.6	20.9	24.0	28.4	35.1
16: 9	201	15.4	16.8	18.7	21.0	24.1	28.5	35.1
16: 10	202	15.4	16.9	18.7	21.0	24.2	28.5	35.1
16: 11	203	15.4	16.9	18.7	21.1	24.2	28.6	35.2
17: 0	204	15.4	16.9	18.8	21.1	24.3	28.6	35.2
17: 1	205	15.5	17.0	18.8	21.2	24.3	28.7	35.2
17: 2	206	15.5	17.0	18.9	21.2	24.4	28.7	35.2
17: 3	207	15.5	17.0	18.9	21.3	24.4	28.8	35.3
17: 4	208	15.5	17.1	18.9	21.3	24.5	28.9	35.3
17: 5	209	15.6	17.1	19.0	21.4	24.5	28.9	35.3
17: 6	210	15.6	17.1	19.0	21.4	24.6	29.0	35.3

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